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CASE REPORT

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A case series of VATS intrapericardial pneumonectomy: a bi-centric experience

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Abstract

Background Intrapericardial pneumonectomy is a complex procedure indicated for large lung tumors where safe dissection of major vascular structures outside the pericardium is unfeasible or when the pericardium itself is invaded. Traditionally managed via open thoracotomy, recent advancements in VATS techniques now allow for intrapericardial pneumonectomy even in cases with extensive tumors or locally advanced disease. In this article, we detail the clinical outcomes and surgical considerations of six patients with non-small cell lung cancer who underwent VATS intrapericardial pneumonectomy. In this article, we detail the clinical outcomes and surgical considerations of six patients with non-small cell lung cancer who underwent VATS intrapericardial pneumonectomy.

Case presentation This study analyzed data from 24 patients who underwent VATS pneumonectomy for non-small cell lung cancer at two thoracic surgery centers in Turkey between January 2015 and March 2024. Among them, 6 patients underwent intrapericardial pneumonectomy; 5 had left pneumonectomy, and 1 had right pneumonectomy. All patients were male, with a mean age of 72.8 years, and a mean tumor size of 6.2 cm. Pericardial invasion was observed in 5 patients. Postoperative complications included respiratory failure and septic shock in one patient, leading to death. Long-term follow-up showed one additional death due to cancer progression; four patients are alive and under routine follow-up.

Conclusions VATS intrapericardial pneumonectomy offers a viable alternative to traditional open surgery for patients with large or locally advanced non-small cell lung cancer, providing enhanced visualization, reduced postoperative pain, and faster recovery. Our multi-center experience with six patients demonstrates the procedure's feasibility and safety, even in challenging cases with pericardial invasion. Despite the complexity of the surgery, the use of advanced VATS techniques and careful intraoperative assessments can lead to successful outcomes. However, given the associated risks, especially with postoperative complications, further studies with larger cohorts are needed to validate these findings and refine surgical techniques.

Keywords Intrapericardial pneumonectomy, Lung cancer, Video-assisted thoracic surgery.

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Background

Intrapericardial pneumonectomy is a challenging procedure preferred in the presence of large lung masses where dissection of major vascular structures outside the pericardium is unsafe or when the pericardium is directly invaded [1]. Traditionally, these cases have been managed through open thoracotomy. However, advancements in VATS techniques have made it possible to perform intrapericardial pneumonectomy even in patients with large tumors or locally advanced disease [2–4]. This technical note presents the clinical outcomes and surgical considerations in six patients who underwent VATS intrapericardial pneumonectomy for non-small cell lung cancer, highlighting the procedural advantages and feasibility of this approach.

Case presentation

The cases included in this study comprise combined data from two different thoracic surgery centers in Turkey. Between January 2015 and March 2024, a total of 24 patients diagnosed with non-small cell lung cancer underwent VATS pneumonectomy at these centers. Verbal and written consent was obtained from all patients. Since the patients' data were anonymized and their consent was obtained, an ethics committee evaluation was not deemed necessary. Among these cases, intrapericardial pneumonectomy was performed on 6 patients. All patients underwent comprehensive preoperative evaluation, including chest CT, PET scans, and endobronchial ultrasound (EBUS) for lymph node assessment. Pulmonary function tests and echocardiography were performed to ensure surgical fitness. Patients received counseling on the procedure, risks, and postoperative expectations.

Table 1 Patient characteristics

Characteristics	*N* = 6
Age (years, mean ± SD)	72.8 ± 6.4
Sex (male)	6
Comorbidity (yes)	
Hypertension	2
Diabetes mellitus	1
Neoadjuvant therapy (yes)	
Chemotherapy	1
Chemoradiotherapy	1
Surgery side	
Left	5
Right	1
Surgery duration (minutes, mean ± SD)	256.7 ± 40.6
Histology	
Adenocarcinoma	2
Squamous cell carcinoma	4
Tumor size (cm, mean ± SD)	6.2 ± 1.1
Nodal status	
N1	2
N2	1
Postoperative complication (yes)	
Cardiac arrhythmia	1
Pneumonia	1
Drainage duration (days, mean ± SD)	2.5 ± 1.1
Hospital stays (days, mean ± SD)	6.3 ± 2.1

SD: Standard deviation

Of these 6 patients, 5 underwent left pneumonectomy and 1 underwent right pneumonectomy. Characteristics of the patients were presented in Table 1. Pathological examination revealed pericardial invasion in 5 patients. In 1 patient, there was no pericardial invasion, but the distance between the tumor and the pericardium in the closest area was 0.5 cm.

In the postoperative period, patients were monitored with clamped chest drains. Once daily, the clamps were released to allow for closed underwater drainage and mediastinal balance adjustment. The goal was to remove the drains on postoperative day 2 in patients without any surgery-related complications. Our criteria for drain removal included:

- The absence of chylous drainage after the initiation of oral feeding.
- No signs of active hemorrhage (e.g., accumulation of coagulum, fresh hemorrhagic drainage exceeding 200 cc/day, or contralateral mediastinal shift).
- The absence of active air drainage suggestive of a bronchopleural fistula.

The mean drainage duration for these six patients was 2.5 ± 1.1 days, while the mean hospital stay was 6.3 ± 2.1 days. Postoperative complications were observed in 2 patients. One patient developed respiratory failure and septic shock due to postoperative pneumonia and died on the 10th postoperative day. In long-term follow-ups, 1 patient died due to cancer progression in the second year after surgery. Routine follow-ups are ongoing for the remaining four patients who are alive.

Technical details of VATS intrapericardial pneumonectomy

The three-portal approach was preferred in patients who underwent intrapericardial VATS pneumonectomy. Patients were positioned in the lateral decubitus position with the operative side facing upwards. The utility incision was made in the 4th or 5th intercostal space and sized to match the tumor dimensions. A camera port was inserted at the 7th intercostal space in the anterior axillary line, and the posterior port was positioned at the 8th or 9th intercostal space in the posterior axillary line. The Alexis wound protector retractor and thoracoscopic surgery instruments were routinely used (Fig. 1). The imaging system utilized was the Karl Storz IMAGE1 S™ 4U camera system, which provided 4 K imaging quality.

Fig. 1 VATS Instruments. These slim-shafted instruments, specifically designed for videothoracoscopic procedures and made from stainless steel, are essential for ensuring safe and comfortable surgical operations

If the tumor invaded the pericardium, or if the dissection of the arteries and veins outside the pericardium was deemed unsafe due to insufficient distance, the pericardium was opened. The pericardium was incised longitudinally, parallel to the hilum, while preserving the phrenic nerve (Fig. 2). Depending on the tumor's location and invasion status, the incision on the pericardium was extended inferiorly and posteriorly, allowing for a circumferential opening. Careful and meticulous dissection was performed, particularly when intrapericardial adhesions were present. The inferior pulmonary vein was divided using an endoscopic stapler inserted through the utility incision. The main pulmonary artery, superior pulmonary vein and the main bronchus were typically divided using a stapler inserted through the posterior port (Figs. 3 and 4). The cartridge lengths and staple thicknesses of endoscopic staplers vary. We typically preferred the ECHELON FLEX™ Powered Vascular Stapler with a 35 mm cartridge length for the pulmonary artery and veins, and a "60 mm Medium/Thick" stapler

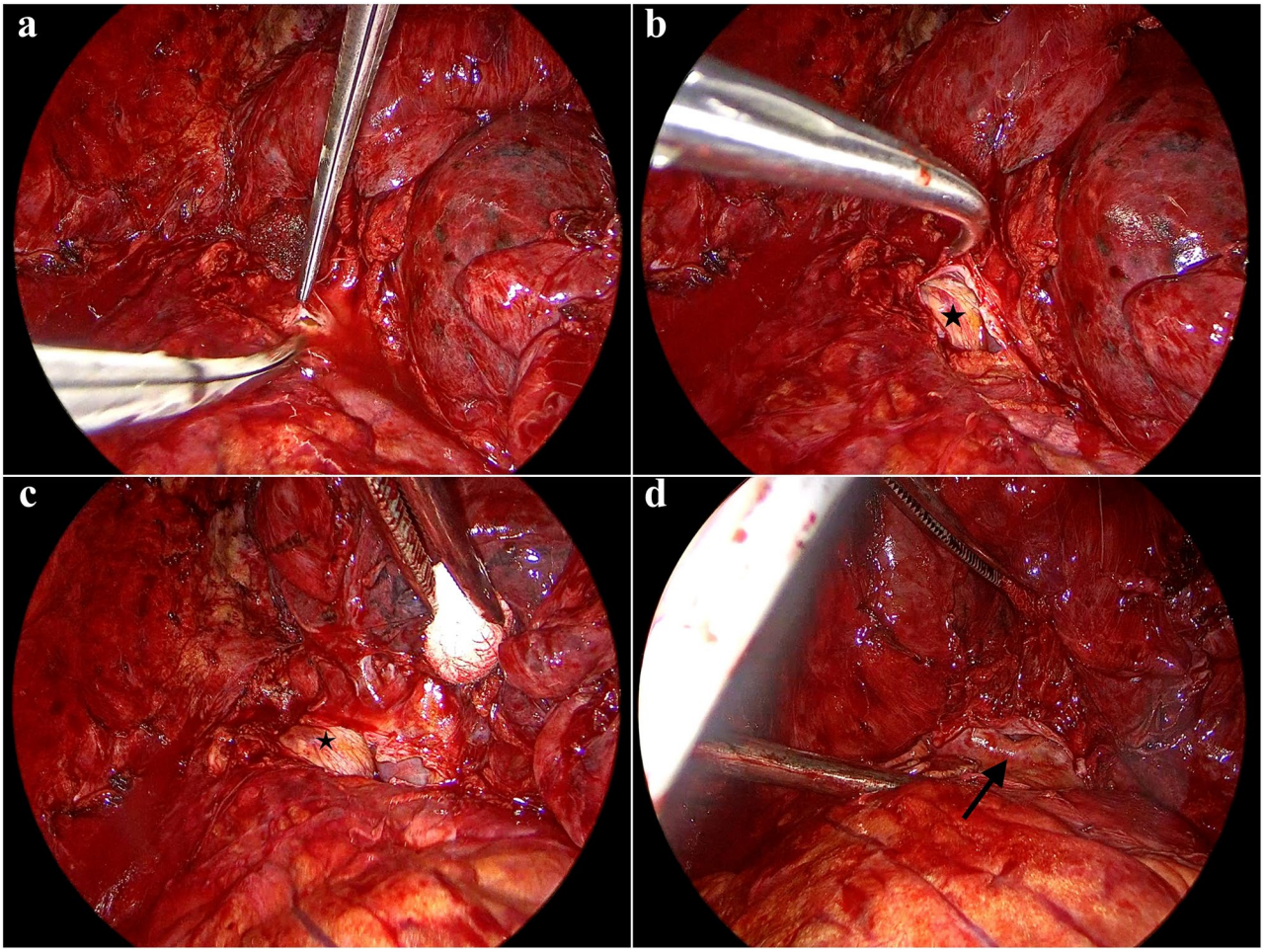

Fig. 2 The pericardium is incised longitudinally parallel to the hilum. The asterisk indicates the left main pulmonary artery, while the arrow indicates the portions of the left superior and inferior pulmonary veins within the pericardium

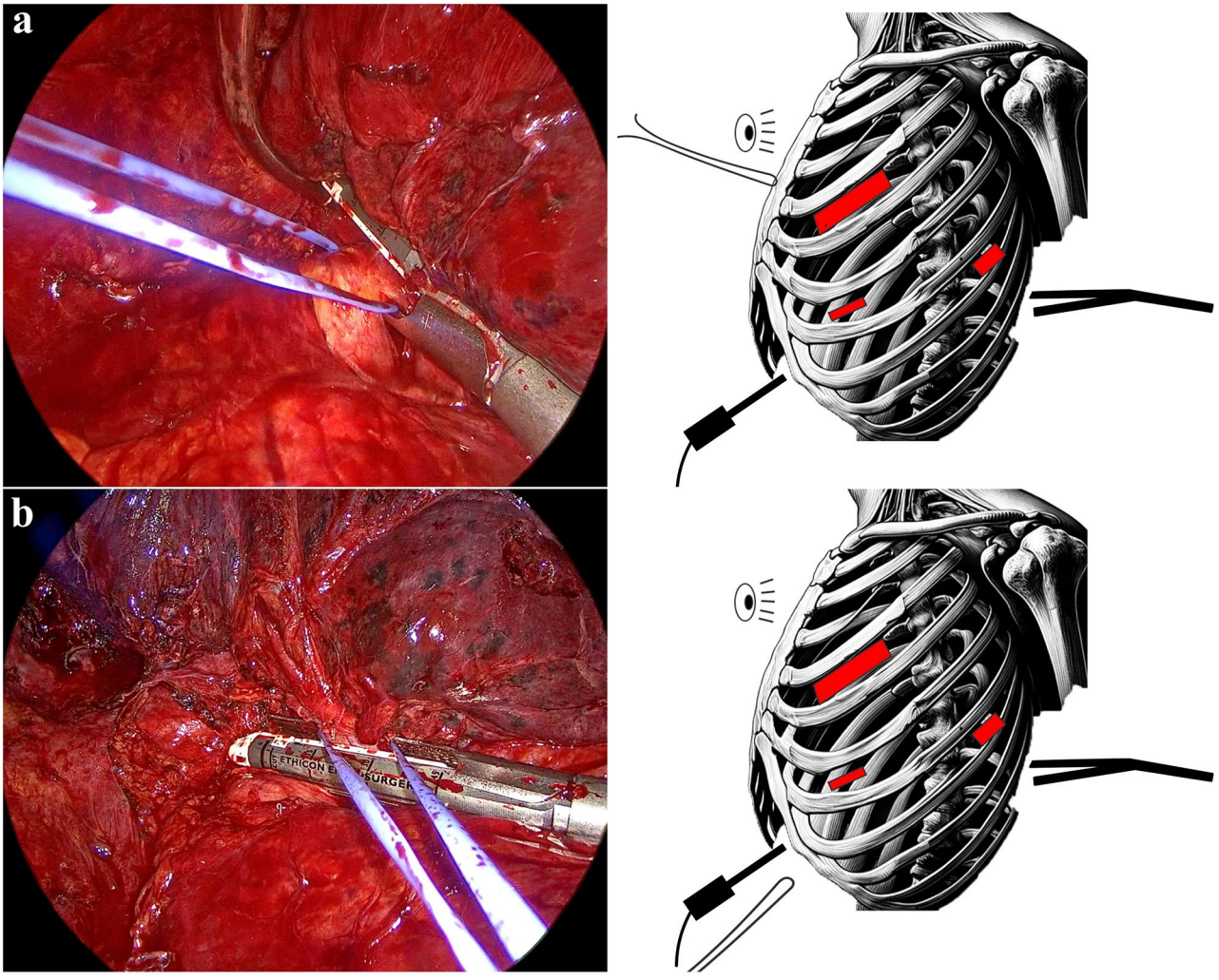

Fig. 3 In Fig. 3a, the left main pulmonary artery is retracted, and the stapler is positioned. In Fig. 3b, the stapler is positioned on the left superior pulmonary vein

cartridge for the main bronchus. However, the intrapericardial portion of the main pulmonary artery can be wider than usual in some cases, making it safer to use a 60 mm cartridge instead of a 45 mm in such situations. Additionally, due to the left main bronchus being longer than the right main bronchus and located under the aortic arch, using a 45 mm stapler cartridge instead of a 60 mm one can be advantageous as it allows for division closer to the carina.

In all patients, the main bronchial stump was reinforced with a thymopericardial fat flap. Finally, following the completion of the resection, an endoscopic organ bag was used for the removal of the specimen from the thorax. In some previous cases, tears in the bag occurred during lung extraction, particularly with larger specimens; therefore, a double endoscopic organ bag was preferred for cases involving large specimen volumes. In VATS pneumonectomy cases, even when the tumor size was not large, central tumor location often caused air trapping, leading to lung inflation, which significantly complicated specimen removal. In such situations, it was occasionally necessary to extend the skin incision (see Fig. 5).

Discussion and conclusions

The transition from traditional open thoracotomy to minimally invasive approaches has demonstrated significant improvements in patient recovery, reduced postoperative pain, and shorter hospital stays [5, 6]. However, thoracoscopic techniques also introduce unique challenges, such as complex hilar dissection and safe management of major vascular structures, particularly when intrapericardial involvement is present.

Due to the large size and central location of the tumor, lung retraction and manipulation are generally difficult in these cases. Therefore, high-quality thoracoscopes, powerful light sources, and high-resolution monitors are crucial. Additionally, thin-shafted and long surgical

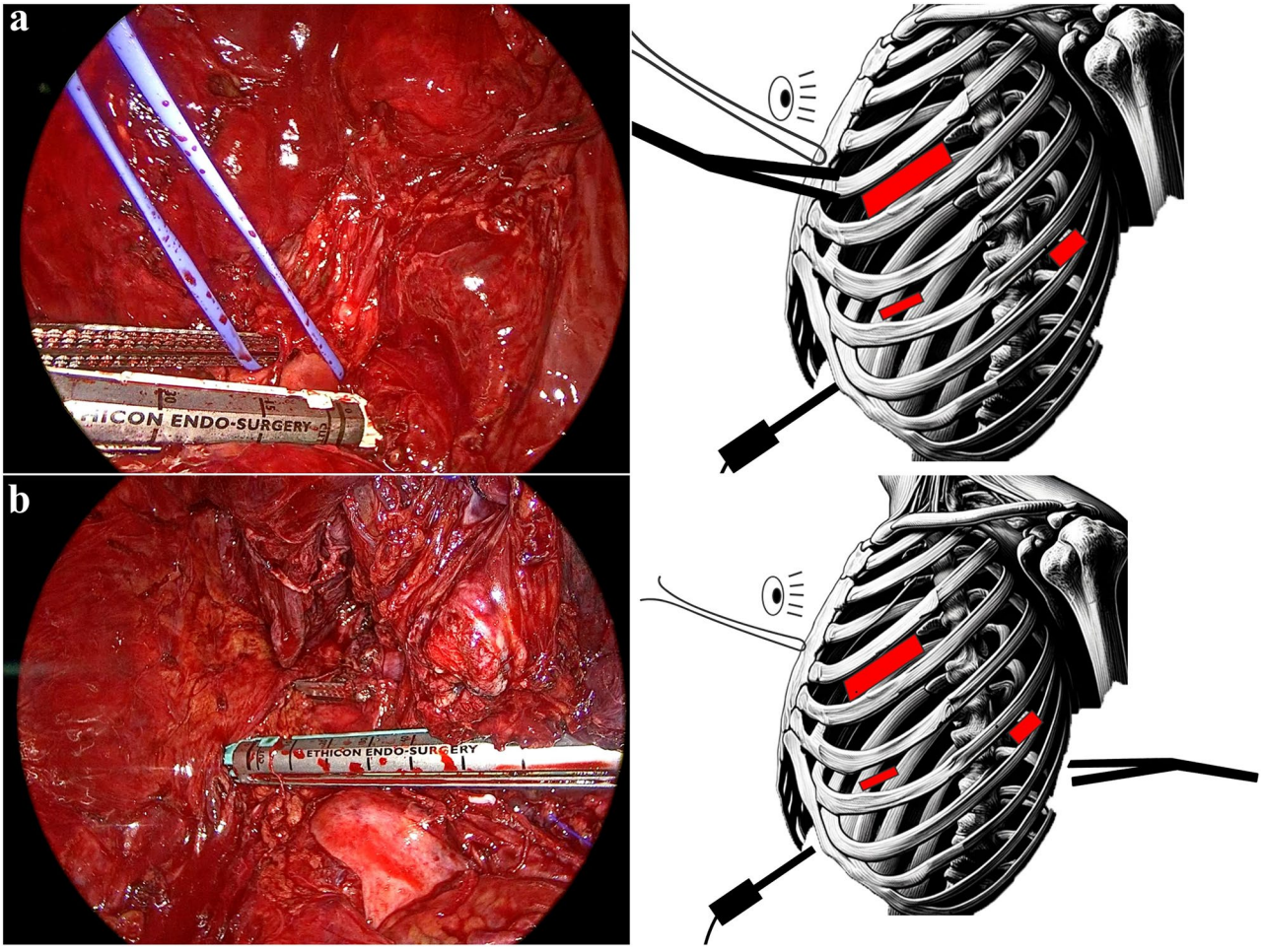

Fig. 4 In Fig. 4a, the stapler is positioned on the left inferior pulmonary vein. In Fig. 4b, the lung is retracted, and the stapler is positioned on the left main bronchus. Note the purposes for which each port is used

instruments designed for video-assisted thoracoscopy are essential for such challenging cases. Initial dissection involves mobilizing the lung and identifying key anatomical landmarks. Although preoperative evaluations assist in the decision to perform pneumonectomy, the feasibility of parenchyma-sparing surgical methods (e.g., sleeve lobectomy) should also be reassessed intraoperatively, and pneumonectomy should be considered as a last resort. If pneumonectomy is decided, the invasion status of the tumor to surrounding structures should be assessed before dividing the hilar structures to determine whether complete resection is possible. If the tumor is considered unresectable, the operation should be terminated. The decision for intrapericardial resection should be made in two primary situations. The first is when there is direct invasion of the pericardium by the tumor. The second is when, despite the absence of pericardial invasion, there is insufficient safe distance for the dissection and division of hilar structures outside the pericardium. In cases with main pulmonary artery invasion, care should be taken to retract the lung gently, and maneuvers that create tension on the hilar structures should be avoided. In case of potential pulmonary artery laceration, appropriate endoscopic vascular clamps, mounted sponges, and suitable suture materials should be readily available.

Another important aspect is the order of division of the hilar structures. While this sequence can vary based on the surgeon's personal preference and the tumor's location, there are several key considerations that must be observed. Dividing the veins first is not only consistent with oncological principles but also technically advantageous. Assuming an anterior approach is preferred in VATS pneumonectomy, the most anterior hilar structure is the superior pulmonary vein. In intrapericardial pneumonectomies, just as in extrapericardial pneumonectomies, the inferior pulmonary vein is divided first, followed by the superior pulmonary vein.

The division of the main bronchus requires adequate lung traction to prevent leaving a long bronchial stump and to achieve a tumor-free surgical margin. The optimal environment for safely performing this maneuver

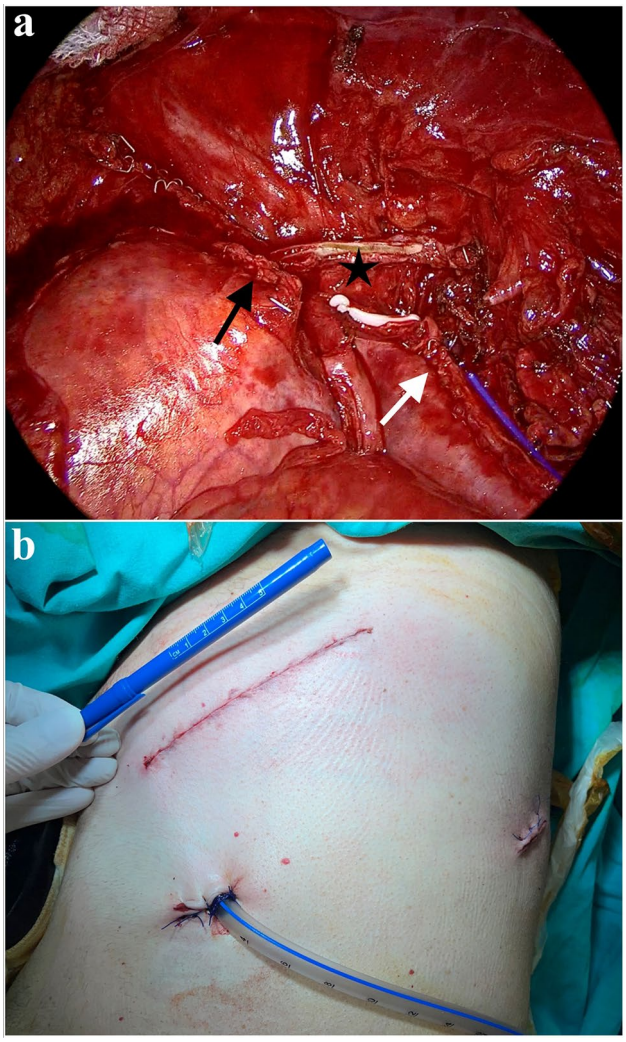

Fig. 5 The view of the surgical field after the completion of the pneumonectomy (Fig. 5a). The asterisk indicates the left main bronchial stump. The black arrow indicates the stump of the left main pulmonary artery, while the white arrow indicates the stump of the left superior pulmonary vein. In Fig. 5b, the skin incisions are shown. In this case, the tumor was approximately 7 cm in size, requiring the utility incision to be made larger than usual

is achieved by leaving the bronchial division until last. Consequently, in a standard VATS pneumonectomy, even when dissections are performed intrapericardially, the order of division for hilar structures is pulmonary veins, main pulmonary artery, and finally the main bronchus.

Side-specific considerations

For intrapericardial right pneumonectomy, to safely divide the main pulmonary artery, careful dissection between the pulmonary artery and the superior vena cava should be performed. When placing the vascular stapler, the superior vena cava and azygos vein should be gently retracted, if necessary, to prevent the stapler tip from damaging these structures.

For intrapericardial left pneumonectomy, during the division of the left main bronchus, it is essential to adequately retract the lung to position the stapler close to the tracheal carina, ensuring a short bronchial stump and preventing complications.

There are reported cases of cardiac herniation and torsion in the literature following intrapericardial right.

pneumonectomy [7, 8]. Therefore, we routinely approximate the pericardium with separate sutures, allowing for pericardial drainage after right pneumonectomy. On the left side, particularly if the defect in the pericardium is small, there is a risk of strangulation of the cardiac structures [9]. Therefore, instead of approximating the pericardium with primary sutures after intrapericardial pneumonectomy, repairing it with a synthetic mesh would be safer. In our cases of intrapericardial left pneumonectomy, we preferred to leave the pericardium widely open to allow free movement of the heart (Fig. 4).

In conclusion, VATS intrapericardial pneumonectomy presents a promising alternative to traditional open surgery, offering superior visualization, reduced postoperative pain, and faster recovery. Our experience supports the feasibility and safety of this approach, even in patients with large or locally advanced tumors. Future studies with larger patient cohorts are needed to further validate these findings and refine the technical aspects of VATS intrapericardial pneumonectomy.

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Author contributions
G.B. and K.C.C. planned the study process and organized the methodology. G.B., and K.C.C. analyzed and interpreted the patient data who underwent VATS pneumonectomy. K.C.C. reviewed the manuscript. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
It has been determined by our institution that an ethics committee approval was not required for this case series. Verbal and written consent was obtained from each patient included in the case series or their legal guardian.

Consent for publication
Informed consent was obtained from the patients included in the study.

Competing interests
The authors declare no competing interests.

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